Letter Report to the USGS Earthquake Hazards Program from the National Earthquake Prediction Evaluation Council (NEPEC), November 2017

Background

The USGS requested that the NEPEC prepare a letter report that responds to several questions concerning the scope and methods for nationwide earthquake forecasting and regional coordination in Cascadia. The Council met October 16 and 17, 2017 in Berkeley, CA and received a number of informative presentations on ongoing related efforts concerning earthquake forecasting at the USGS. The discussion follows up on a 2015 letter report from the NEPEC entitled, "Recommendations from NEPEC on USGS research and development activities in the area of operational earthquake forecasting", which represents previous guidance on the development of an Operational Earthquake Forecasting (OEF) capability at the USGS, https://earthquake.usgs.gov/aboutus/nepec/reports/NEPEC_advice_OEF_Dec2015.pdf.

The following are our recommendations based on these presentations and on our review of recent publications and material concerning OEF provided by the USGS. The recommendations have been grouped by topic, the first covering earthquake forecasting within the USGS (Questions 1, 4, 5), and the second addressing the questions specific to Cascadia (Questions 2, 3).

We distinguish two forms of earthquake forecasting: Operational Aftershock Forecasting (OAF) and Operational Earthquake Forecasting (OEF). OAF has been used for many years by the California Earthquake Prediction Evaluation Council (CEPEC) (Roeloffs and Goltz, 2017 Seismol. Res. Lett.) when moderate magnitude events trigger interest in the possibility of subsequent earthquake activity. In this sense, we consider OAF as an event-initiated approach. In contrast, OEF is not triggered by specific events, but rather is an automated process through which earthquake probabilities are being continuously updated and disseminated (e.g., Jordan et al., 2011 Annals Geophys.).

Questions and NEPEC Responses

The SESAC (Scientific Earthquake Studies Advisory Committee) has cautioned that, given the number of EHP priorities competing for fixed funds, USGS investment in operational earthquake forecasting should be in response to user needs. At this meeting, we will summarize the work we've done to learn about user needs and the strategic path that we've designed in light of those findings.

Q1. We would appreciate commentary from the Council on whether our strategic path is appropriately constructed and scaled to deliver operational forecasts to meet user needs.

The NEPEC commends the efforts on the part of the OEF developers to understand user needs, including hosting two Powell Center meetings that were attended by a diverse set of stakeholders. Users (including emergency managers, first responders, utilities, natural resource companies, insurance companies, etc.) have consistently emphasized a need for low-latency earthquake forecasting, including statements and map products carried through to hazard, made available and updated in near-real-time immediately after specific moderate and larger earthquakes. Some earthquake scientists from New Zealand and Italy emphasized that during the protracted, complex sequences those nations are currently experiencing, continuous forecasting (i.e., OEF) is beneficial.

The work since the last NEPEC letter shows impressive gains in operationalizing the Reasenberg and Jones, 1989 (RJ) OAF model, and the developers appear to be ready to incorporate an ETAS module as it is finalized. We heard that automating OEF was a solvable problem, and agree that this should be pursued. By automated OEF, we mean continuously-running forecasting software for the nation, the results of which should be provided to the public. NEPEC emphasizes that the goal should be continuous OEF rather than event-initiated OAF. Fully operationalized OEF will provide key advantages over OAF:

1) In many ways it will be simpler, since fewer arbitrary decisions are needed to consider overall seismicity rather than a subjectively defined sequence.
2) OAF can be misleading because it fails to capture background hazard. This deficiency will be most apparent and important at relatively long times after and/or relatively large distances from a mainshock. In effect, it is not possible to do OAF right without doing OEF: our basic definition of aftershocks is based on the background rate of seismicity, so aftershock probabilities should fade into the background rate, which is not zero.
3) Providing earthquake forecasts at all times respects the hazard-risk separation principle, allowing stakeholders to decide when a situation requires their action, and ensures that we will provide information when a swarm precedes a damaging earthquake (e.g., L'Aquila, Italy in 2009) but no single event exceeds an arbitrary threshold required to make an aftershock forecast.
4) A fully operationalized system will be better maintained and calibrated if it is generating results at all times rather than only after large earthquakes.
5) A fully operationalized OEF system provides an important outreach and education tool, as it will familiarize the public and higher-level stakeholders with products that will be most critically needed during an active aftershock or swarm sequence.

The development of a robust, sustainable, fully operationalized system for earthquake forecasting has clearly been delayed by a lack of stable support for a scientific programmer. The user community, including the public, has expressed a clear need for a suite of forecast products. Neither initial development nor long-term operation of an OAF or OEF system will be possible without the necessary commitment of IT support. The NEPEC is not the appropriate body to comment on the priority of OEF development relative to other activities of the USGS, but agreed that to be successful, such an effort demands adequate short- and long-term support.

The NEPEC was also informed about issues concerning the communication of the forecasts to the public and specific users. To make OEF fully useful, education, training and communication between users is needed, and additional work to accommodate new types of data (e.g., spatial information, hazard curves for technical users) should continue.

Given the range of statistical approaches for OEF (discussed in more detail below) and the likelihood (if not certainty) that credible alternative models will yield different probabilities, the NEPEC suggests that developers of OAF and OEF begin to consider, and take steps towards, formal ensemble modeling.

In your December, 2015 report, you stated: "NEPEC is convinced that some version of an ETAS approach will be an improvement over the RJ [Reasenberg & Jones, 1989] method for OEF and that the USGS should continue pursuing, developing, and testing an ETAS method. Before it replaces the RJ method in OEF, NEPEC would like to see the results of testing the method, including the satisfactory performance of well-developed codes to implement it in OEF, and a demonstration that ETAS performs better than the RJ approach."

Q4. We seek your recommendation on whether our implementation of ETAS is scientifically suitable for replacement of RJ as the basis for operational temporal and spatiotemporal forecasts.

The Council was impressed by the testing that has been done since the last NEPEC meeting to demonstrate the superiority of the basic ETAS method over the RJ method, including both spatial and temporal components. A fully operational OAF system using the RJ module is under development and close to completion. In parallel, the implementation of an operational temporal ETAS module is under development and the advisory template for the NEIC is being evaluated. The details of the remaining coding effort, including the minor technical decisions that have to be made to implement ETAS nationwide, were not entirely clear. The Council recommends that these efforts continue to move forward: waiting for an ETAS module to be completed would derail progress with the operational part of the system, which has proved to be more challenging than initially considered. Once a fully operational ETAS module is developed, the RJ module can be retained for testing (or replaced) with little effort. Documentation will need to be updated to describe the change, once it occurs.

Further, while the immediate focus is development of an operationalized OAF system implementing RJ after a mainshock of sufficient magnitude, the Council strongly recommends that the USGS press forward to develop a fully operationalized nationwide OEF system that carries calculations, combining the background rate of seismicity and earthquake clustering, through to hazard. From this continuous forecast, customized products can be made by stakeholders and the USGS can issue advisories and notifications when desired.

Also in your 2015 report, you provided useful commentary about the UCERF3-ETAS forecasting method, including: "NEPEC was intrigued by the ongoing effort to develop [that] time-dependent earthquake forecasting capability using a combination and extension of ETAS and the UCERF3 time-independent model…. Such an approach clearly needs more testing and evaluation before it can be considered for moving into an operational mode. However, if that or some similar system could be demonstrated to have practical value, NEPEC would likely endorse it enthusiastically."

Q5. We would like your recommendations on whether the UCERF3-ETAS method, as currently formulated, documented and tested, is scientifically suitable for use by USGS, NEPEC and CEPEC in supporting operational earthquake forecasting in California. More generally, your feedback on what level of documentation and testing would be deemed necessary and sufficient for such purposes would be helpful.

Although we recognize that this proposition is difficult to test, the NEPEC believes that combining UCERF3 with ETAS (UCERF3-ETAS) is likely to lead to more accurate assessment of earthquake hazard in California. In particular, it will increase the estimated probability of low-probability, high-impact events when earthquakes occur near major faults. More accurate estimates of the probability of such events will be of use to the insurance industry and perhaps other highly sophisticated users of earthquake forecasts, if the data can be provided quickly. Existing efforts to test UCERF3-ETAS (e.g., Page and van der Elst, "Turing-style Tests for UCERF3 Synthetic Catalogs", in review) seem appropriate and thus far have not uncovered any troubling discrepancies between statistical measures of the observed California earthquake catalog and synthetic catalogs produced by UCERF3.

For these reasons, the NEPEC believes that it is appropriate to use UCERF3-ETAS in support of operational earthquake forecasting in California on an ad hoc basis, following earthquakes that are deemed significant by virtue of their size or proximity to major faults. However, it is our consensus that an autonomous, automated implementation of UCERF3-ETAS is a long way off, and is not a realistic or desirable short-term goal given that basic spatio-temporal ETAS can be implemented soon. For the foreseeable future, the NEPEC envisions that UCERF3-ETAS results will contribute to ad-hoc ensemble forecasts.

Some time at the meeting was devoted to discussing the issue of sequentially releasing forecasts, based on different algorithms that might be viewed as incompatible. For example, how would the public respond if the probability of a very large but low-probability aftershock were to suddenly increase, if a UCERF3-ETAS forecast were released after an ETAS forecast? Possible approaches include publishing forecasts with uncertainties (e.g., include a range of probabilities with each forecast as they are produced). This would be satisfactory if the probability ranges overlapped. Guaranteeing such an outcome seems to require anticipating, for example, the results of a UCERF3-ETAS forecast based upon an ETAS forecast. The NEPEC would be interested to know if useful "rules of thumb", i.e., highly simplified calculations, could be developed towards this end.

In an ideal world, a UCERF3-ETAS forecast would be available quickly enough to fulfill the strong desire for a low-latency product. This is not considered practical at the present time. Finally, the need for expert opinion to vet a UCERF3-ETAS forecast gives rise to the possibility that such a forecast might be interpreted differently by the USGS and CEPEC, giving rise to the undesirable possibility of competing authoritative messages. It is the view of the Council that these are important questions that deserve more discussion than we were able to devote to them at our October 2017 meeting. We would be interested in hearing more about this topic at our next meeting.

At this meeting we will discuss the coordination of forecasting and communication in California and in the Cascadia region, these discussions being prompted by USGS plans for a nation-wide forecasting system and by the Cascadia earthquake communication plan received from CREW.

Q2. We would appreciate advice on how the responsibilities for composing and communicating forecasts should be coordinated among the various responsible agencies and councils.

The NEPEC is encouraged to see recent steps towards improved coordination of forecasting and communication in the Pacific Northwest, and applauds the CREW report as a good first step and as a statement of stakeholder needs. The CREW report does not, however, make a consistent recommendation as to who would issue alerts, warnings, or advisories should such a situation arise. The Director of the USGS has the responsibility to issue geologic hazard warnings. In California, however, the state emergency management agency has established a protocol for soliciting expert scientific opinion and issuing earthquake "Advisories" at the state level, and the USGS defers to California under a semi-formal agreement negotiated many years ago. This agreement has worked satisfactorily on at least nine occasions, but has posed difficulties twice. The issue of whether Advisories for the Cascadia region would be issued by state officials or by the USGS is one that requires more discussion. The USGS perhaps should work with the states involved to design coordinated response plans similar to the California Earthquake Advisory Plan rather than ceding responsibility for issuing warnings to the states, especially as there is the potential for Cascadia subduction zone developments that would warrant action by up to three states and two countries. Similar issues will likely arise in other regions and it remains to be seen if a state-by-state solution is advisable.

Q3. We would like the Council's comments on the Cascadia earthquake communication plan, including the recommendation that two standing committees be formed: a scientific body (CREEC, suggested to be a NEPEC subcommittee), and a risk communication group (CERC).

NEPEC supports the plan to constitute a council like CREEC (Cascadia Region Earthquake Evaluation Council). Slow slip and tremor, and Puget Sound tectonics, as discussed by the Gomberg et al. 2015 Open-File report, are aspects of earthquake hazard in the Cascadia region that are not well addressed by current USGS earthquake forecasting efforts.

Setting up CREEC as a subcommittee of NEPEC, as proposed in the CREW report, has potential advantages. These include (1) defining a clear channel of communication with the USGS and NEPEC; (2) providing access to the experience of NEPEC scientists in thinking about earthquake forecasting issues; (3) ensuring that the committee convenes periodically in the likely event that no urgent situations arise; and (4) providing access to legal immunity for CREEC members should the outcome of CREEC deliberations lead to an unforeseen adverse outcome. In addition, the model of a NEPEC subcommittee may be the best model for similar future subcommittees that may be constituted to respond to earthquake forecasting and related issues that arise in other parts of the country not covered by CEPEC or CREEC.

NEPEC recognizes, however, that having CREEC as a subcommittee of NEPEC would be an administrative burden on the USGS and could introduce delays in relaying consensus messages through NEPEC to USGS management, potentially reducing their value or accuracy in an earthquake forecasting situation. Hence, NEPEC is open to other structures for CREEC and future additional regional committees.

The CREW report recommends that CREEC be convened anytime an automated aftershock forecast suggesting increased hazard in the Cascadia region is released, which does not appear practical. Presumably the report's authors envision CREEC providing context that emergency managers and the public might request and find valuable. OEF is currently envisioned as a generic national effort; but CREEC's regional expertise could be useful in framing the way forecasts for the Cascadia region are computed, for example by taking into account the variation in aftershock behavior with earthquake depth.

NEPEC also liked the plan to create a council like CERC (Cascadia Earthquake Risk Communication Committee). The regional emergency managers are enthusiastic about being more closely in touch, given the large number of emergency managers and their rapid turnover. Whether CERC should be a temporary group, or instead be a mechanism for recurring contacts across Cascadia is not yet clear. This group might primarily exist to maintain lines of communication and contacts across state and national boundaries. It could also take an active role in pre-scripting public response talking-points and/or designing an earthquake hazard alert-level scheme similar to that in place for volcanic hazards in Oregon and Washington. One complication is that each separate state is independent, thereby complicating whether the CERC can issue an authoritative report.